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(71) Applicant: KOYO SEIKO CO., LTD.
Chuo-ku Osaka 542 (JP)

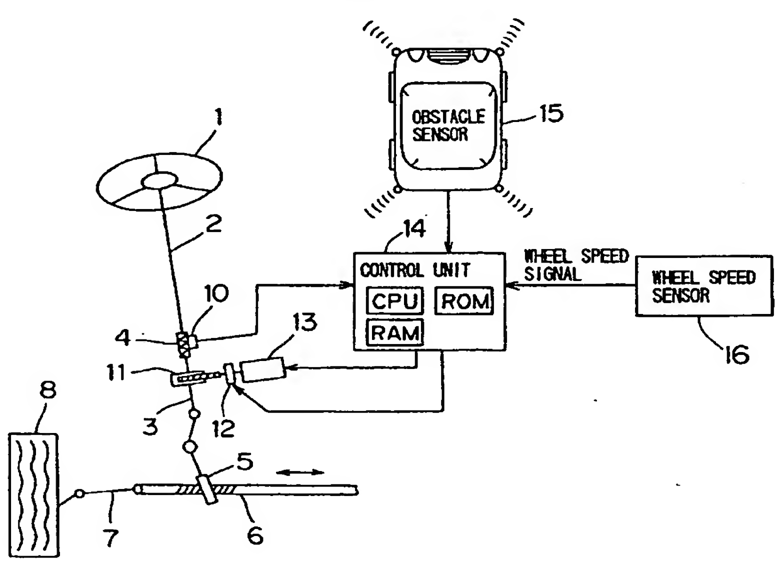
(72) Inventors:
- Shimizu, Yoshinobu,
c/o Seiko Co., Ltd.
Osaka 542 (JP)
- Nakano, Shiro,
c/o Seiko Co., Ltd.
Osaka 542 (JP)

(74) Representative: Bohnenberger, Johannes, Dr. et al
Meissner, Bolte & Partner
Postfach 86 06 24
81633 München (DE)

(54) **Electric power steering system**

(57) An electric power steering system of this invention can inform the driver of potential danger before a vehicle enters a dangerous situation. The occurrence of dangerous situations is determined based on a signal from an obstacle sensor (15). If a steering wheel (1) is turned in a dangerous situation, a warning control is performed by control means (14) on a motor (13). The motor outputs a torque for t1 second, for example, which counters against turning of the steering wheel (1). Then, the motor enters a "non-assist" state wherein no current is applied thereto for t2 second. If an intermittent counter torque is applied by the motor, it is hard to turn the steering wheel. The steering wheel is caused to vibrate, thereby preventing the vehicle from being steered to collide with an obstacle. The driver is warned of the danger through the vibration caused in the steering wheel.

FIG. 2



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates in general to an electric power steering system and more particularly to an electric power steering system capable of informing a driver of potential danger by providing control by way of safety precaution before a vehicle enters a dangerous situation.

Description of the Prior Art

As a prior art system related to the present invention, a system for warning of a vehicle accidentally drifting out of the traffic lane is disclosed in Japanese Unexamined Patent Publication No.6-76200 (1994). This prior art system is mainly directed to a system for warning a driver when the vehicle starts drifting out of the lane resulted from his falling asleep. This system keeps watch on the traffic lane (a line on a road) using a television camera and gives a warning to the driver when the vehicle starts drifting out of the lane. To give the warning, a vibration actuator incorporated in the steering wheel directly vibrates a spoke portion of the steering wheel.

Dangerous situations which are expected to occur while the vehicle is moving include not only in cases where the vehicle is not steered because the driver has fallen asleep behind the wheel, but also those where the driver is steering the wheel.

Referring to FIG. 1, suppose that Vehicle C1 in the left lane and Vehicle C2 in the right lane are moving in the same direction on a divided road R with two lanes each way; Vehicle C1 is running somewhat ahead relative to Vehicle C2, and Vehicle C2 is approaching Vehicle C1 from the right rear and is moving at a faster speed than Vehicle C1.

When the vehicles so positioned are moving, if the driver of Vehicle C1 is not aware of the approach of Vehicle C2 from the right rear and tries to change lanes, as shown by the broken line in the figure, a dangerous situation may occur which could cause a collision.

Such danger does not stem from the fact that the driver has, for example, fallen asleep behind the wheel and has not actively steered the vehicle, as is the case described in the prior art system, but rather resulted from the fact that the driver carelessly has failed to check his rear to make sure that he may safely change lanes and has turned the steering wheel.

The prior art system does not fully assure the prevention of occurrence of dangerous situations caused by such a carelessness of the driver. It is extremely dangerous to cause vibration in the steering wheel in response to the detection of the white dividing line by the television camera when the driver is actively turning the steering wheel to change lanes.

SUMMARY OF THE INVENTION

In view of the foregoing, it is the main object of the present invention to provide a system performing control by way of safety precaution adapted to avoid dangerous situations which could be caused due to the intention of the driver to turn the steering wheel.

According to a mode of the present invention, an electric power steering system which is combined with a steering mechanism including a steering wheel and which has a motor for producing a steering assist force when the vehicle is steered by means of the steering wheel, the power steering system is characterized by comprising:

obstacle detecting means for determining the presence of an obstacle in the periphery of the vehicle; and

warning control means for driving the motor to cause vibration in the steering wheel when an obstacle is detected by the obstacle detecting means.

According to another mode of the invention, the aforesaid electric power steering system is characterized by further comprising means for determining whether the steering wheel is turned or not, wherein the warning control means drives the motor so as to vibrate the steering wheel stronger when the steering wheel is not turned than when it is turned.

According to another mode of the invention, it is characterized in that the warning control means does not perform the warning control when the steering wheel is within a range of play with the middle point at the center thereof, wherein the steering wheel is not practically involved in steering operation.

According to still another mode of the invention, it is characterized in that the warning control means regulates a value of current and/or voltage applied to the motor to a predetermined target value, and fluctuates the target value cyclically when an obstacle is detected by the obstacle detecting means.

According to another mode of the invention, it is characterized in that the warning control means so drives the motor as to produce an intermittent counteractive force against turning of the steering wheel.

According to yet another mode of the invention, it is characterized in that the warning control means provides control such that the motor alternates an "adverse-assist" state wherein the motor produces a counteractive force against turning of the steering wheel, and a "non-assist" state wherein the motor produces no counteractive force.

According to a mode of the present invention, in response to forecast of danger due to the approach of an obstacle, the vibration is caused in the steering wheel thereby warning the driver of potential danger. The vibration in the steering wheel is caused by, for example, cyclic fluctuation of a target control value of the motor. With the cyclic fluctuation of a target control value of the motor, the steering assist force produced by the motor cyclically

fluctuates when the vehicle is steered by means of the steering wheel.

According to another mode of the invention, the steering wheel vibrates stronger when the vehicle is moving straight with the steering wheel kept unturned than when the vehicle is steered to change its travelling course. Accordingly, when the vehicle is moving straight, the driver is assuredly warned of potential danger by a strong vibration of the steering wheel. On the other hand, while the steering wheel is being turned, the steering wheel vibrates not stronger on which the driver is allowed to keep turning, thereby warning the driver of danger without making the driver feel scared.

According to the present invention having the foregoing modes, when a dangerous situation is forecast, the driver is prevented from steering the vehicle to a more dangerous direction whereby traffic accident is avoided in advance and the travelling safety is improved.

Particularly, a relatively strong vibration is caused in the steering wheel when the vehicle is moving straight, whereas a relatively mild vibration is caused when the vehicle is changing its travelling course, so that the travelling safety may be improved without making the driver feel scared.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram for illustrating a dangerous situation expected to occur while vehicles are moving.

FIG. 2 is a diagram schematically illustrating the whole arrangement of an electric power steering system according to an embodiment of the present invention.

FIG. 3 is a graphical representation showing the relation between torque voltage T_V and torsional angle.

FIG. 4 is a flow chart schematically illustrating an outline of warning control in an electric power steering system according to an embodiment of the present invention.

FIG. 5 is a memory map showing the content of a memory of a control unit.

FIG. 6 is a flow chart showing the whole routine of warning control performed by a control unit.

FIG. 7 is a flow chart showing the whole routine of warning control performed by a control unit.

FIG. 8 is a detailed flow chart showing the routine of warning control (strong) against the rightward turning of the steering wheel.

FIG. 9 is a detailed flow chart showing the routine of warning control (strong) against the leftward turning of the steering wheel.

FIG. 10 is a detailed flow chart showing the routine of warning control (mild) against the rightward turning of the steering wheel.

FIG. 11 is a detailed flow chart showing the routine of warning control (mild) against the leftward turning of the steering wheel.

DESCRIPTION OF THE EMBODIMENT

FIG. 2 is a diagram schematically illustrating the whole arrangement of an electric power steering system according to an embodiment of the present invention. Referring to FIG. 2 firstly, the arrangement and operations of an electric power steering system according to this embodiment of the present invention will be described.

A steering mechanism includes a steering wheel 1, an input shaft 2 connected to the steering wheel 1 and an output shaft 3 coupled to the input shaft 2. The input shaft 2 and the output shaft 3 are linked to each other by means of a torsion bar 4. Connected to the downstream side of the output shaft 3 is a pinion gear 5 which is meshed with a rack shaft 6 extending in the lateral direction of a vehicle. Tires 8 are connected to the rack shaft 6 by means of a tie rod 7.

Such a steering mechanism incorporates an electric power steering system serving as a steering aid system. The electric power steering system includes a torque sensor 10 provided in association with the torsion bar 4, a decelerator 11 engaged with the output shaft 3, a motor 13 for applying a drive force through a clutch 12 to the decelerator 11 and a control unit 14. The control unit 14 is supplied with torque voltage T_V from the torque sensor 10 and vehicle speed signal from a wheel speed sensor which is not shown in the figure. It is also supplied with signal from an obstacle sensor 15.

The obstacle sensor 15 includes, for example, four sensors mounted to the four corner portions of the vehicle for outputting a signal indicative of the detection of an obstacle approaching any one of the right and left corners in the front and rear of the vehicle. The obstacle sensor may be a sensor, such as an ultrasonic sensor or an infrared ray sensor, which irradiates a signal of ultrasonic wave or infrared rays to detect the reflection thereof. Alternatively, the obstacle sensor may be a combination of an image reading device, such as CCD, and an image processing unit. Such an obstacle sensor 15 has been known in the art and therefore, the detailed description thereof is omitted.

During normal steering assist control wherein no signal is applied from the obstacle sensor 15, the control unit 14 regulates the value of current supplied to the motor 13 according to a torque voltage T_V of the torque sensor 10 and a vehicle speed signal, and also On/Off of the clutch 12. When a signal is supplied from the obstacle sensor 15, the control unit 14 performs warning control which will be described hereinbelow.

Now, operations during the normal steering assist control is described. Firstly, the input shaft 2 is rotated by a torque applied to the steering wheel 1. The output shaft 3 receives a load including a road reactive force applied through the pinion gear 5, the rack shaft 6, the tie rod 7 and the tires 8 which are coupled to the downstream side of the output shaft 3. Accordingly, the rotation of the input shaft 2 is not directly transmitted to the output shaft 3, but causes torsion in the torsion bar 4

because of the load affecting the steering system. The torsion, or a relative rotational angular displacement between the input shaft 2 and the output shaft 3 is detected as a torque voltage T_V by the torque sensor 10 to be transmitted to the control unit 14. The control unit 14 in turn regulates the value of current supplied to the motor according to a torque voltage T_V and a vehicle speed signal, so that the motor 13 may output a predetermined torque. The output torque is applied through the clutch 12 to the decelerator 11 to be amplified for the rotation of the output shaft 3. When it is not necessary to apply an output torque of the motor 13 to the output shaft 3, the clutch 12 is switched off by the control unit 14.

When the input shaft 2 is rotated either rightward or leftward by a torque applied to the steering wheel 1, the control unit 14 normally causes the motor 13 to produce a torque such that the output shaft 3 is rotated in the same direction as the input shaft 2 rotates. This reduces the load on the steering system which is received as a reactive force by the steering wheel 1, and thus the steering wheel 1 can be turned with less force.

FIG. 3 is a graphical representation showing the relation between a torque voltage T_V supplied by the torque sensor 10 and a torsional angle which occurs in the torsion bar 4 (relative rotational angular displacement between the input shaft 2 and the output shaft 3).

In this embodiment, when the torque sensor 10 outputs the torque voltage of 2.5 V, as shown in FIG. 3, the steering wheel 1 is at the middle point with the input shaft 2 receiving neither a rightward nor a leftward torque. When the steering wheel 1 is turned to the right, the input shaft 2 is rotated rightward but the output shaft 3 cannot follow the rotation of the input shaft 2 because of the load, and thus torsion is caused in the torsion bar 4. The torque voltage T_V of the torque sensor 10 varies corresponding to a degree of torsion in the torsion bar 4. When the steering wheel 1 is turned to the right, the greater the amount of torsion, the greater the value of the torque voltage T_V. Conversely when the steering wheel 1 is turned to the left, the torque voltage T_V of the torque sensor 10 decreases inversely of the amount of torsion. When a torque voltage T_V of the torque sensor 10 is in the range of $2.3 \leqq T_V \leqq 2.7$ wherein 2.5 V is at the center thereof, which 2.5 V is a value when the steering wheel 1 is positioned at the middle point, it may be considered that the steering wheel 1 has returned substantially to the middle point (in a state where the steering wheel 1 is not turned neither rightward nor leftward), and therefore, the same control operation may be performed as when the steering wheel 1 is at the middle point. When a torque voltage T_V is in the range of $1.9<T_V<3.1$, the steering wheel 1 is in a so-called range of play. When the steering wheel 1 is in this range of play, the steering wheel 1 is not practically involved in the steering operation, and therefore, the warning control to be described hereinbelow is not performed.

When the steering wheel 1 is turned and the vehicle actually changes its travelling course, a level of the torque voltage T_V is, for example, 3.1 V or more, if it is turned rightward; whereas, a level of the torque voltage T_V is, for example, 1.9 V or less if it is turned leftward.

During the normal steering assist control, the control unit 14 shown in FIG. 2 regulates a value of current applied to the motor 13 in accordance with a torque voltage T_V of the torque sensor 10, which varies as shown in FIG. 3, and a vehicle speed signal. More specifically, when a value of the torque voltage T_V exceeds 2.7 V, the motor 13 is caused to rotate rightward, for example, thereby producing a steering assist torque for rotating the output shaft 3 rightward (in the same direction as that the steering wheel 1 is turned).

Conversely when a value of the torque voltage T_V is lower than 2.3 V, the motor 13 is caused to rotate leftward, for example, thereby producing a steering assist torque for rotating the output shaft 3 leftward.

In this embodiment, the direction of the steering assist torque produced by the motor 13 is switched either rightward or leftward by switching the rotational direction of the motor 13. Instead of switching the rotational direction of the motor 13, the decelerator 11 may be utilized to mechanically switch the direction of the steering assist torque applied to the output shaft 3.

FIG. 4 is a flow chart schematically illustrating an outline routine of the warning control by way of safety precaution in an electric power steering system according to the embodiment of the present invention.

Referring to FIG. 4, the control unit 14 firstly determines whether any dangerous situation exists or not (Step P1), based on a signal from the obstacle sensor 15. In a dangerous situation, it determines whether the steering wheel 1 is turned to the right or to the left, in response to a predetermined torque voltage T_V (e.g., $T_V \geqq 3.1$ V, or $T_V \leqq 1.9$ V) applied from the torque sensor 10 ("YES" in Step P2). According to the determination, the control unit 14 performs on the motor 13 the following warning control instead of the normal steering assist control.

It causes the motor 13 to output a torque for t1 second, which operates to rotate the output shaft 3 in a direction counter to that the steering wheel is turned. Such a torque in the counter direction is applied for a fractional moment, such as 0.01 second, and therefore, the output shaft 3 is not actually turned in the counter direction but a steering force through the input shaft 2 and a steering assist torque applied in the counter direction by the motor 13 are offset each other so that the output shaft 3 is substantially locked (Step P3). Thereafter the motor 13 is in a "non-assist" state for t2 second in which the motor 13 outputs no torque (Step P4).

If it is determined that the dangerous situation still exists (Step P1) and then is determined that the steering wheel 1 is turned (Step P2), the "adverse-assist" state in Step P3 and the "non-assist" state in Step P4 are repeated alternatively.

This is how the warning control by way of safety precaution proceeds in this embodiment. During the warning control operations, the alternation between the "adverse-assist" state and the "non-assist" state causes

the steering wheel 1 to vibrate in a certain rhythmic pattern, thereby the steering wheel hardly be turned, and thus, the driver may be informed of the occurrence of danger. Additionally, the driver is inhibited from steering the vehicle toward where the danger might be occurred, so that a collision may be avoided in advance.

Instead of entering the "non-assist" state in Step P4, the motor 3 may produce a weaker "adverse assist" torque than that of Step P3 or produce a little assist torque.

With reference to the detailed flow charts, more specific content of the warning control will be described.

FIG. 5 is a memory map showing the content of a memory which is required in the control unit 14 (see FIG. 2) for performing specific controls. The control unit 14 comprises electronic devices such as, CPU, ROM and RAM. The content of the memory map shown in FIG. 5 is stored, for example, in RAM.

As shown in FIG. 5, the control unit 14 comprises a danger avoidance counter DAC, a direction flag DF, a control flag CF, a torque counter TC1, a torque counter TC2, a torque voltage register TVR1 and a torque voltage register TVR2. The danger avoidance counter DAC counts the number of times of warning control execution. The direction flag DF is required for determining which direction, rightward or leftward, the steering wheel 1 is turned; if the steering wheel 1 is turned to the right, it is set to "0", whereas if the steering wheel 1 is turned to the left, it is set to "1". The control flag CF determines whether the steering wheel 1 is returned to the middle point or not; each time the steering wheel 1 returns to the middle point, it is set to "0". The torque counter TC1 counts the timing of sampling of a torque voltage T_V applied by the torque sensor 10; it outputs a signal indicative of a timing to sample a torque voltage T_V every 10 milliseconds period during which 20 times of 0.5 milliseconds interruptions are counted. The torque counter TC2 counts the timing of sampling of a torque voltage T_V applied by the torque sensor 10; it outputs a signal indicative of a timing to sample a torque voltage T_V every 100 milliseconds period during which 200 times of 0.5 milliseconds interruptions are counted. The torque voltage register TVR1 holds the latest five sampled torque voltages at 10 milliseconds intervals, if a torque voltage T_V is sampled in response to each timing signal applied by the torque counter TC1. The torque voltage register TVR2 holds the latest five sampled torque voltages at 100 milliseconds intervals, if a torque voltage T_V is sampled in response to each timing signal applied by the torque counter TC2.

Out of the counters, flags and registers shown in FIG. 5, the danger avoidance counter DAC and the torque counter TC1 are used for control after having been set to "0" by the initialization routine.

FIGs. 6 and 7 are flow charts each showing the whole routine of the warning control performed by the control unit 14.

The warning control is executed by way of interrupt handling which occurs, for example, every 0.5 milliseconds.

In this control, a current applied to the motor 13 during the normal steering assist control is first subject to a limiter processing (Step S1).

In the subsequent Step S2, whether the danger avoidance counter DAC is "0" or not is determined. If DAC is not "0", any of the warning controls has already started, and therefore, the flow proceeds to Step S25 described hereinbelow.

If, on the other hand, the danger avoidance counter DAC is "0", the normal steering assist control is still underway. In this case, whether the direction flag DF is "0" or "1 " is determined (Step S3). That is, whether the steering wheel 1 has turned the input shaft 2 to the right or to the left is determined. If the direction flag DF is "1" indicating that the input shaft 2 has been turned to the left, then whether a level of the torque voltage T_V is 2.3 V or more is determined (Step S4). On the other hand, if the direction flag DF is "0" indicating that the input shaft 2 has been turned to the right, then whether a level of the torque voltage T_V is 2.7 V or less is determined (Step S6).

As shown in FIG. 3, when a level of the torque voltage T_V is 2.3 V or more despite the leftward turning of the input shaft 2, or when a level of the torque voltage T_V is 2.7 V or less despite the rightward turning of the input shaft 2, the steering wheel 1 is in a range to be considered to have returned to the middle point. Accordingly, with the steering wheel 1 being in this range, the control flag CF is set to "0" in Step S5 or Step S7 and that the steering wheel 1 is positioned substantially at the middle point is stored.

Thus in Steps S3 through S7, determination is made on whether or not the steering wheel 1 is in the range to be considered to have returned to the middle point; if the steering wheel 1 is in this range, "0" is written in the control flag CF.

In the subsequent Steps S8, S9 and S11, a level of the torque voltage T_V is determined. As shown in FIG. 3, when the steering wheel 1 is at the middle point, a level of the torque voltage T_V is 2.5 V, and the level varies depending upon whether the steering wheel 1 is turned to the right or to the left. If T_V<2.5 V, it is determined that the steering wheel 1 is turned to the left, otherwise it is determined that the steering wheel 1 is turned to the right (Step S8).

If the steering wheel 1 is turned to the left, whether a torque voltage T_V is 1.9 V or less is determined. If T_V>1.9 V, it is determined that the steering wheel 1 is in the range of play, as shown in FIG. 3, wherein the steering wheel 1 is not practically involved in the steering operation, and therefore, the flow proceeds to Step S22 omitting the warning control.

If $T_V \leqq 1.9$V, the vehicle is changing its travelling course by turning the steering wheel 1 to the left, and accordingly, the direction flag DF is set to "1" at this time (Step S10). If the torque voltage T_V marks more than 2.5

V in Step S8, it is determined that the steering wheel 1 is turned to the right, and whether a torque voltage T_V at this time is 3.1 V or more is determined (Step S11). If the torque voltage T_V is less than 3.1 V, the steering wheel 1 is in a so-called range of play wherein the steering wheel 1 is not practically involved in the steering operation, and therefore, the flow proceeds to Step S22 omitting the warning control. If, on the other hand, the torque voltage T_V is 3.1 V or more, the vehicle is changing its travelling course by turning the steering wheel 1 to the right. Accordingly, the direction flag DF is set to "0" at this time and that the steering wheel 1 is turned rightward is stored (Step S12).

Thereafter, the content of the control flag CF is determined (Step S13). If the control flag CF is "0" indicating that the steering wheel has returned to the middle point, the vehicle is moving straight, and in this state the steering operation will be started. At this time, the content of the direction flag DF is determined (Step S14); if the steering wheel 1 is turned leftward, a torque voltage T_V 50 milliseconds before is compared to 1.9 V, which is a boundary value for determining whether the steering wheel 1 is in the range of play or not (Step S15). If the steering wheel 1 is out of the so-called range of play, being involved in the steering operation, the warning control against the leftward turning of the steering wheel (mild) is performed such that the warning control may be performed without interfering with the steering operation (Step S16).

On the other hand, if the steering wheel 1 is in the range of play, the vehicle is moving straight; in order to keep the vehicle moving straight, the warning control against the leftward turning of the steering wheel (strong) is performed thereby inhibiting the turning of the steering wheel (Step S17).

Similarly in Step S14, if the direction flag DF is "0" indicating that the steering wheel 1 is turned rightward, whether a torque voltage T_V 50 milliseconds before is more than 3.1 V or not is determined. If it is 3.1 V or more, the warning control against the rightward turning of the steering wheel (mild) is performed (Step S19). On the other hand, if a torque voltage T_V 50 milliseconds before is less than 3.1 V, the warning control against the rightward turning of the steering wheel (strong) is performed (Step S20).

If, in Step S13, the control flag CF is "1" indicating that the steering wheel 1 has not returned to the middle point, the state of the direction flag DF is determined in Step S21; if the steering wheel 1 is turned leftward, the warning control against the leftward turning thereof (mild) is performed (Step S16). If the steering wheel 1 is turned rightward, the warning control against the rightward turning thereof (mild) is performed (Step S19).

In this manner, in the warning control, the motor 13 produces either a weak or a strong "adverse assist" force (a counteractive force against turning of the steering wheel) depending upon whether the steering wheel 1 is practically involved in the steering operation or is in the vicinity of the middle point. The reason for providing different levels of the "adverse assist" force is because if a great "adverse assist" force is applied to the steering wheel 1 while the driver is turning it, the driver may feel as if the steering wheel 1 were forced back, and therefore, a need exists for causing such a mild vibration in the steering wheel 1 as may not make the driver feel that way.

On the other hand, when the vehicle is moving straight, the application of such a great "adverse assist" force does not make the driver feel as if the steering wheel were forced back, and therefore, a strong warning control is performed to cause a relatively strong vibration in the steering wheel 1.

When the steering wheel 1 is in the range of play, the warning control is not performed, and in Step S22, a target current value of the motor 13 is subject to the limiter processing using a current value for the normal steering assist control. Based on a count value of the torque counter TC, a torque voltage T_V applied by the torque sensor 10 is sampled every 10 milliseconds to be stored in the torque voltage register TVR1 (Step S23-1). In the torque voltage register TVR1, the oldest data is abandoned and a new data is written. Based on a count value of the torque counter TC2, a torque voltage T_V applied by the torque sensor 10 is sampled every 100 milliseconds to be stored in the torque voltage register TVR2 (Step S23-2). In the torque voltage register TVR2, the oldest data is abandoned and a new data is written.

Thereafter, the normal steering assist control is performed using a current value limited in Step S22 (Step S24).

If, in Step S2, the danger avoidance counter DAC is not "0" indicating that the warning control has already started, the state of the direction flag DF is determined in Step S25; if the steering wheel 1 is turned leftward, the state of the control flag CF is determined (Step S26). Similarly if the steering wheel 1 is turned rightward, the state of the control flag CF is determined (Step S27). The control flag CF indicates whether the steering wheel 1 has returned to the middle point or not; depending upon the indication of the control flag CF, there is performed any one of the warning controls which are against the rightward turning of the steering wheel (strong), against the rightward turning thereof (mild), against the leftward turning thereof (strong) and against the leftward turning thereof (mild) as shown in FIGs. 8 through 11 respectively.

FIG. 8 is a detailed flow chart showing the routine of the warning control (strong) against the rightward turning of the steering wheel 1.

Referring to FIG. 8, firstly a signal indicative of danger applied by the obstacle sensor 15 is read in (Step S31) for determination on whether a dangerous situation exists or not (Step S32).

When it is determined that there is a dangerous situation, the control flag CF is set to "0" and a maximum value of the current supplied to the motor 13 is set to, for example, "361" corresponding to 65A (Step S34). Then, the danger avoidance counter DAC is caused to start

counting with a control current value set to "ff30" while its count is less than "20" (Step S36), and the motor 13 is regulated using the set current value as the target current value of the motor 13 (Step S37). A count value of the danger avoidance counter DAC is incremented by 1 every 0.5 milliseconds (Step S38).

Thus, the motor 13 is driven so as to output a leftward assist force for 10 milliseconds which counters the rightward turning of the steering wheel 1.

Nextly, the control current value is set to "0" while the count value of the danger avoidance counter DAC is in a range from 20 to less than 180 (Steps S39, S40) so that no current is applied to the motor (Step 37). Then, the count value of the danger avoidance counter DAC is incremented (Step S38).

This brings the motor into the "non-assist" state for 80 milliseconds.

Thereafter, while the count value of the danger avoidance counter DAC is in a range from 180 to less than 200, the control current value is set again to "ff30" so that the current of that value may be applied to the motor 13, and the count value of the counter DAC is incremented (Step S41 → S42 → S37 → S38). Accordingly, the motor 13 produces an "adverse assist" force for 10 milliseconds.

In like manner, the "non-assist" state for 80 milliseconds keeps alternating with the "adverse-assist" state for 10 milliseconds until the count value of the danger avoidance counter DAC reaches "380" (Step S47), when the control current value is set to "0" for the normal steering assist control (Step S48).

The current value for the normal steering assist control is set to "0" in order to prevent the warning control from being abruptly switched to the normal steering assist control at a high current value.

FIG. 9 is a flow chart showing the routine of the warning control against the leftward turning of the steering wheel 1 (strong). This flow chart has the same content with that of the warning control against the rightward turning thereof (strong) as shown in FIG. 8, except that current values set in accordance with count values of the danger avoidance counter DAC are different.

The flow charts showing the routines of the warning control against the rightward turning of the steering wheel 1 (mild) and against the leftward turning thereof (mild) shown in FIGs. 10 and 11 respectively, have the same content with that shown in FIG. 8, except that current values set in accordance with count values of the danger avoidance counter DAC are different and that the following steps are performed: before reading a signal indicative of danger, determination is made in Step S100 whether a torque voltage T_V is greater than (a T_V 50 milliseconds before + 0.1 V) or not, thereby detecting a quick turning of the steering wheel 1, whereas determination is made in Step S101 whether a torque voltage T_V is greater than (a T_V 500 milliseconds before + 0.3 V) or not, thereby detecting a slow turning of the steering wheel 1; and before reading a signal indicative of danger, determination is made in Step S110 whether a torque voltage T_V is less than (a T_V 50 milliseconds before - 0.1 V) or not, thereby detecting a quick turning of the steering wheel 1, whereas determination is made in Step S111 whether a torque voltage T_V is less than (a T_V 500 milliseconds before - 0.3 V) or not, thereby detecting a slow turning of the steering wheel 1.

If the aforesaid warning control is performed, vibration is caused in the steering wheel 1. The algorithm of vibration production, or the contents of the warning controls shown in FIGs. 8 through 11 will be summarized as follows:

(a) a period of 10 milliseconds: a target current value of the motor is set to a value which is counter to that of a steering force ("adverse assist");
(b) a period of 80 milliseconds: a target current value of the motor is set to "0" ("non-assist");
(c) a period of 10 milliseconds: a target current value of the motor is set to a value counter to that of a steering force;
(d) a period of 80 milliseconds: a target current value of motor is set to "0";
(e) a period of 10 milliseconds: a target current value of the motor is set to a value counter to that of a steering force; and
(f) a period of 0.5 milliseconds: normal steering assist control (warning interval)

The above described control steps (a) through (f) are repeated until it is determined that there is no dangerous situation.

The aforementioned specific millisecond periods are given merely by way of example, and in principle, a period of any milliseconds that allows the steering wheel 1 to be vibrated in a rhythmic pattern may be used.

The warning control according to the embodiment described above adopts a set of three times of vibration to be caused in the steering wheel 1. In dangerous situations, however, the steering wheel 1 may be caused to vibrate continuously regardless of the number of vibrations of the set.

Claims

1. An electric power steering system suitable for use with a vehicle steering mechanism (1, 2, 3, 4, 5, 6) including a steering wheel (1) and a motor (13) for producing a steering assist force when the vehicle is steered by the steering wheel (1), the power steering system comprising:
obstacle detecting means (15) for determining the presence of an obstacle in the periphery of the vehicle; and
warning control means (14) for driving the motor (13) to cause vibration in the steering wheel (1) when an obstacle is detected by the obstacle detecting means (15).

2. An electric power steering system as set forth in Claim 1, further comprising means for determining whether the steering wheel (1) is turned or not, wherein the warning control means (14) is adapted to drive the motor (13) so as to vibrate the steering wheel (1) stronger when the steering wheel (1) is not turned than when it is turned.

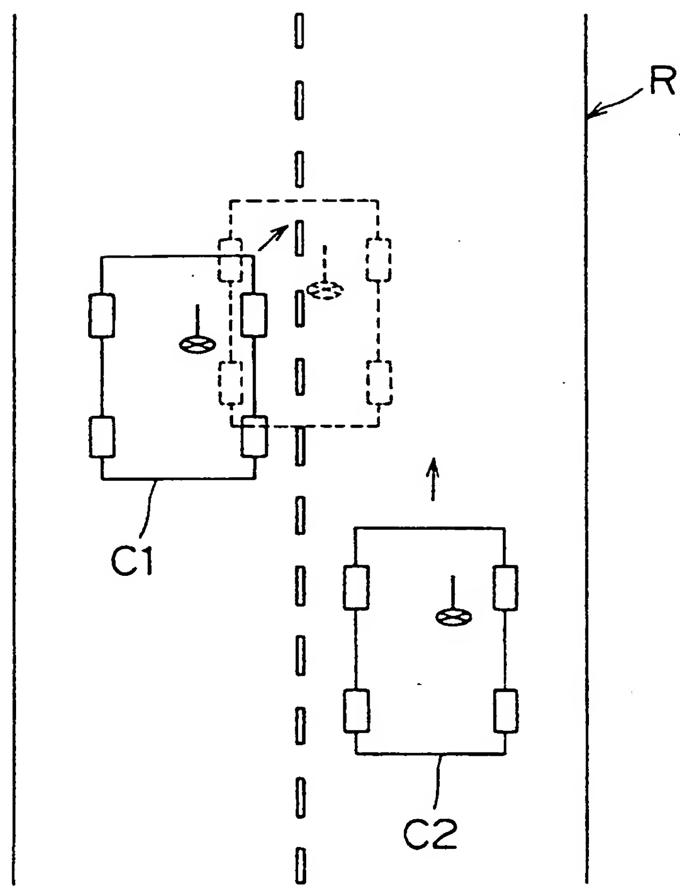
3. An electric power steering system as set forth in Claim 1 or 2, wherein the warning control means (14) is adapted not to perform the warning control when the steering wheel (1) is within a range of play about the middle point of steering, wherein the steering wheel (1) is not practically involved in steering operation.

4. An electric power steering system as set forth in any one of Claims 1 to 3, wherein the warning control means (14) is adapted to regulate a value of current and/or voltage applied to the motor (13) to a predetermined target value, and to fluctuate the target value cyclically when an obstacle is detected by the obstacle detecting means (15).

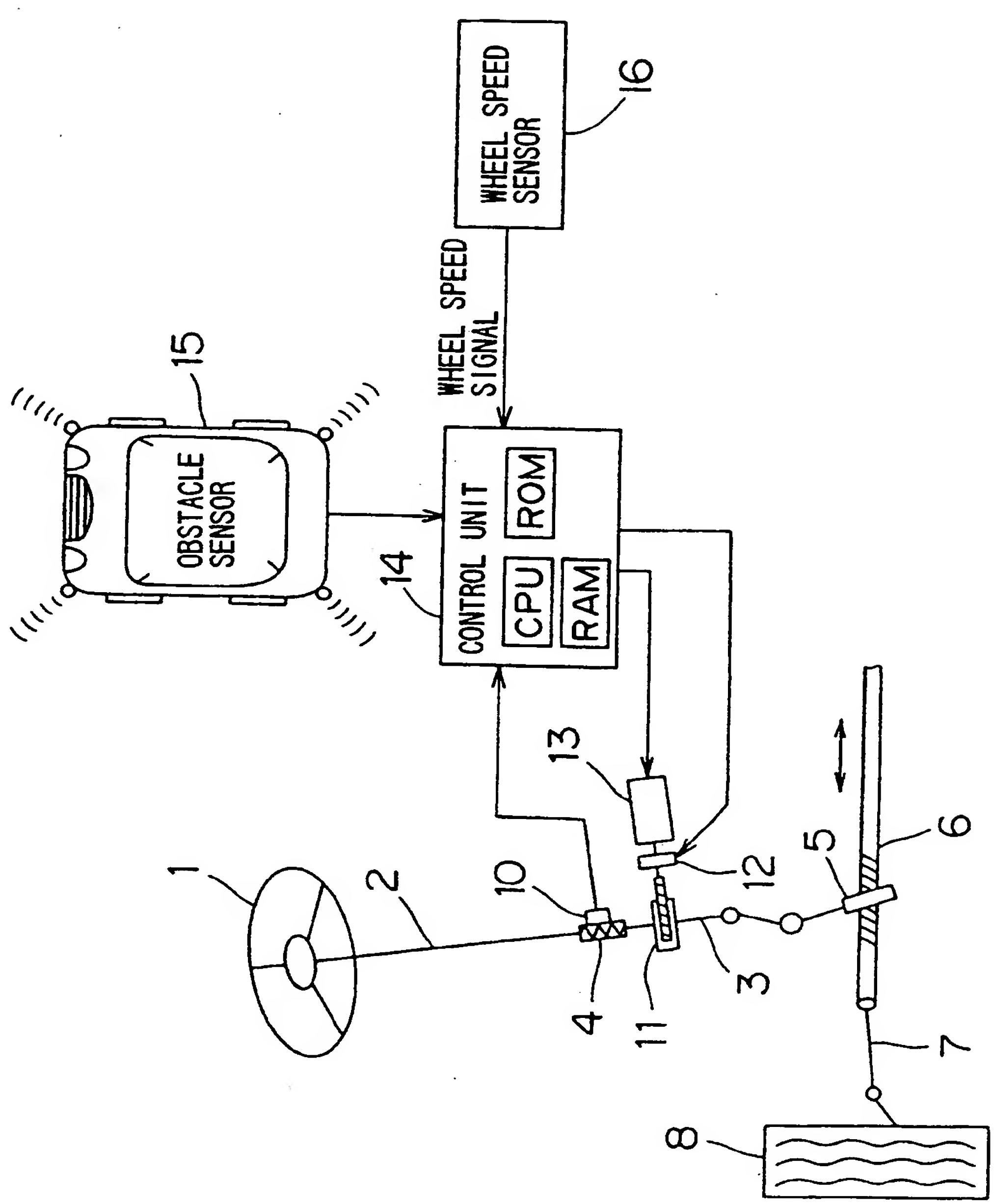
5. An electric power steering system as set forth in any one of Claims 1 to 3, wherein the warning control means (14) is adapted to drive the motor (13) so as to produce an intermittent counteractive force against turning of the steering wheel (1).

6. An electric power steering system as set forth in any one of Claims 1 to 3, wherein the warning control means (14) is adapted to control the motor (13) to alternate an "adverse-assist" state wherein the motor (13) produces a counteractive force against turning of the steering wheel (1), and a non-assist" state wherein the motor (13) produces no counteractive force.

FIG. 1



F I G. 2


OBSTACLE SENSOR
15
14
CONTROL UNIT
CPU
ROM
RAM
WHEEL SPEED SIGNAL
WHEEL SPEED SENSOR
16
1
2
10
4
11
3
12
13
5
6
7
8

F I G. 3

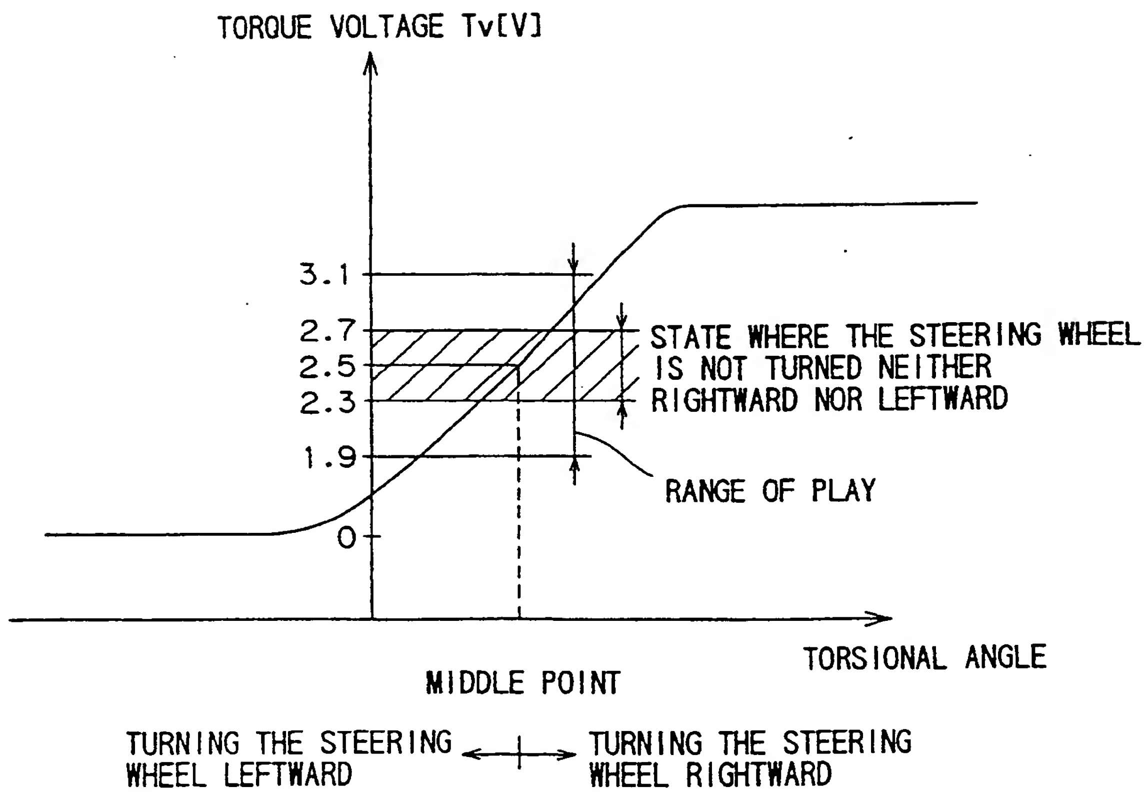

TORQUE VOLTAGE Tv[V]
3.1
2.7
2.5
2.3
1.9
0
STATE WHERE THE STEERING WHEEL IS NOT TURNED NEITHER RIGHTWARD NOR LEFTWARD
RANGE OF PLAY
TORSIONAL ANGLE
MIDDLE POINT
TURNING THE STEERING WHEEL LEFTWARD
TURNING THE STEERING WHEEL RIGHTWARD

FIG. 4

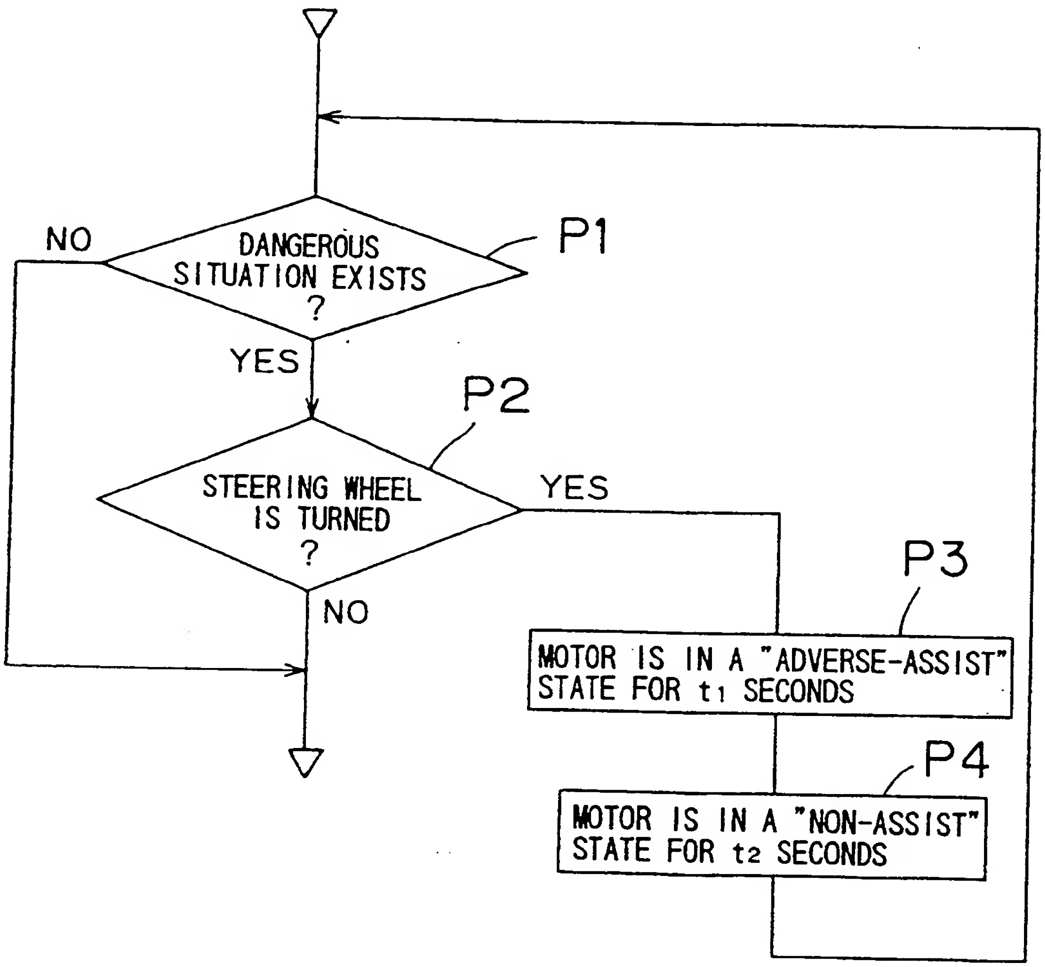

DANGEROUS SITUATION EXISTS ?
P1
NO
YES
STEERING WHEEL IS TURNED ?
P2
YES
NO
P3
MOTOR IS IN A "ADVERSE-ASSIST" STATE FOR t_1 SECONDS
P4
MOTOR IS IN A "NON-ASSIST" STATE FOR t_2 SECONDS

FIG. 5

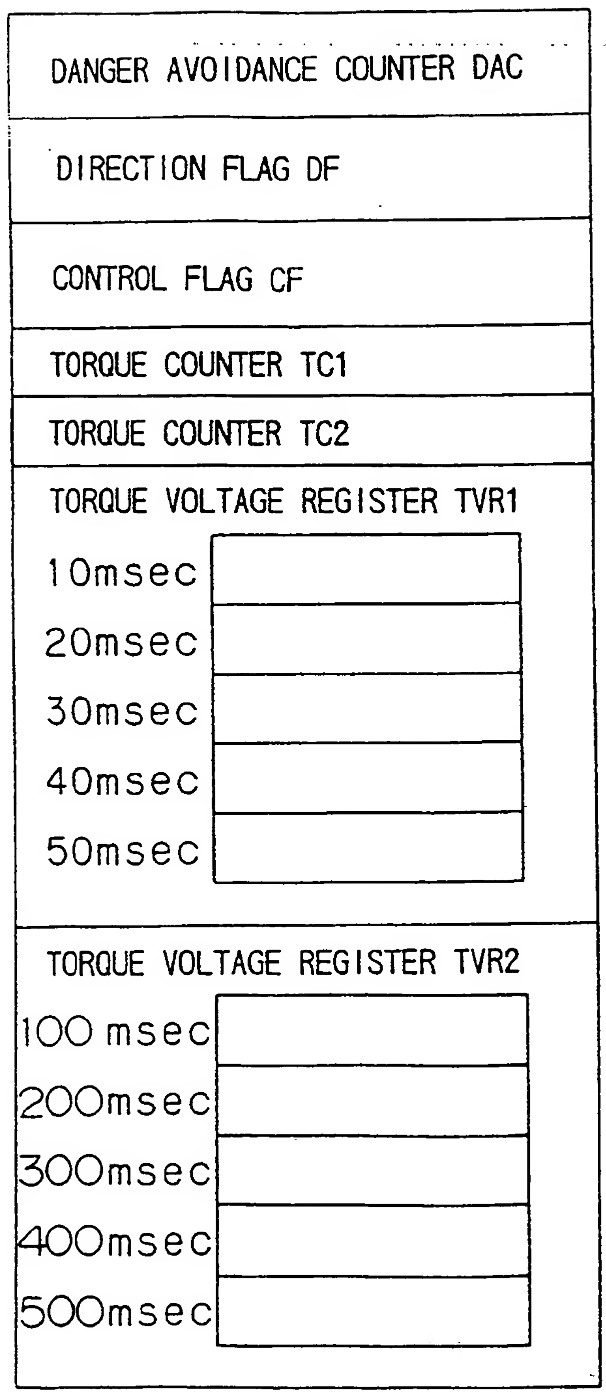

DANGER AVOIDANCE COUNTER DAC
DIRECTION FLAG DF
CONTROL FLAG CF
TORQUE COUNTER TC1
TORQUE COUNTER TC2
TORQUE VOLTAGE REGISTER TVR1
10msec
20msec
30msec
40msec
50msec
TORQUE VOLTAGE REGISTER TVR2
100 msec
200msec
300msec
400msec
500msec

FIG. 6

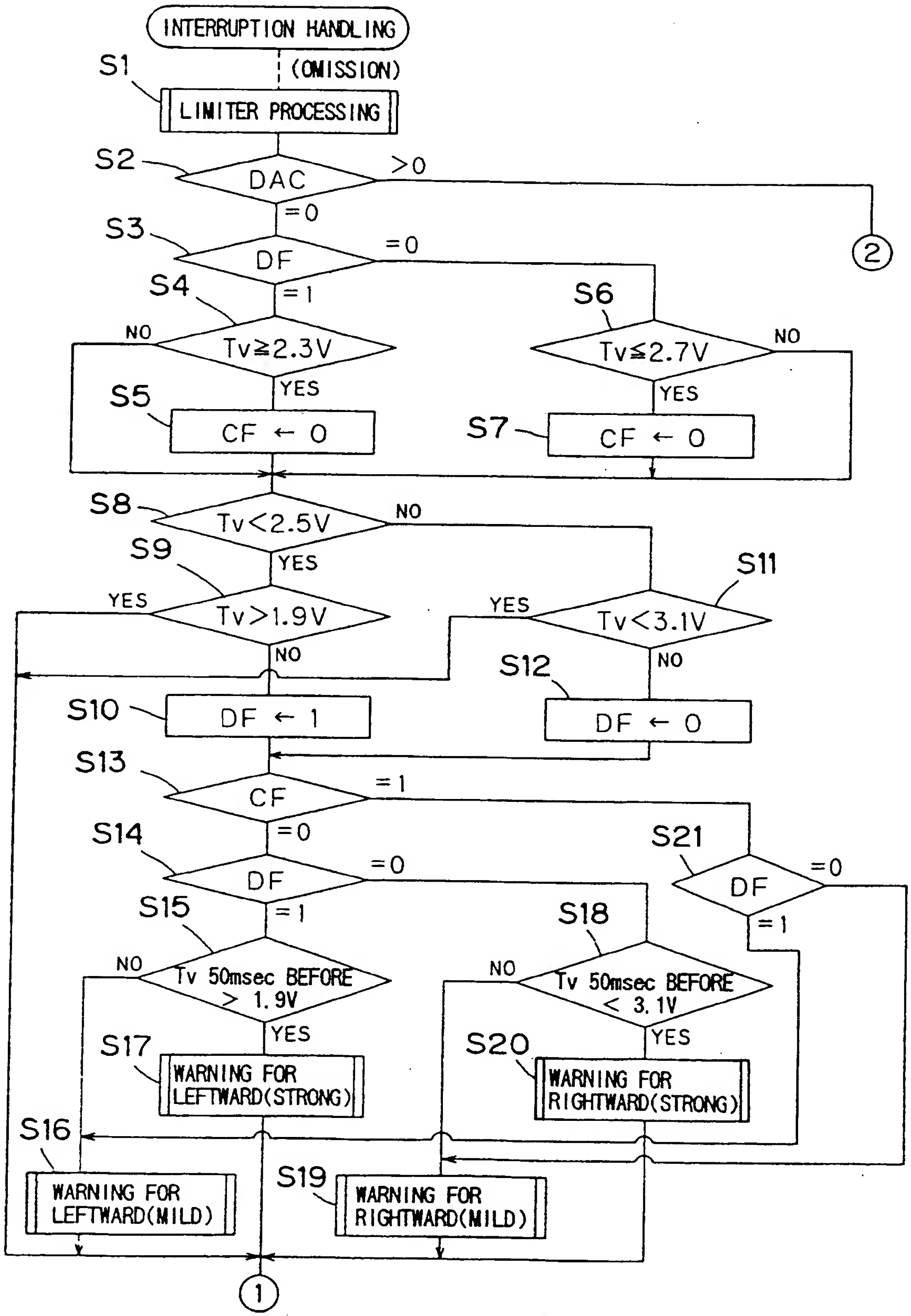
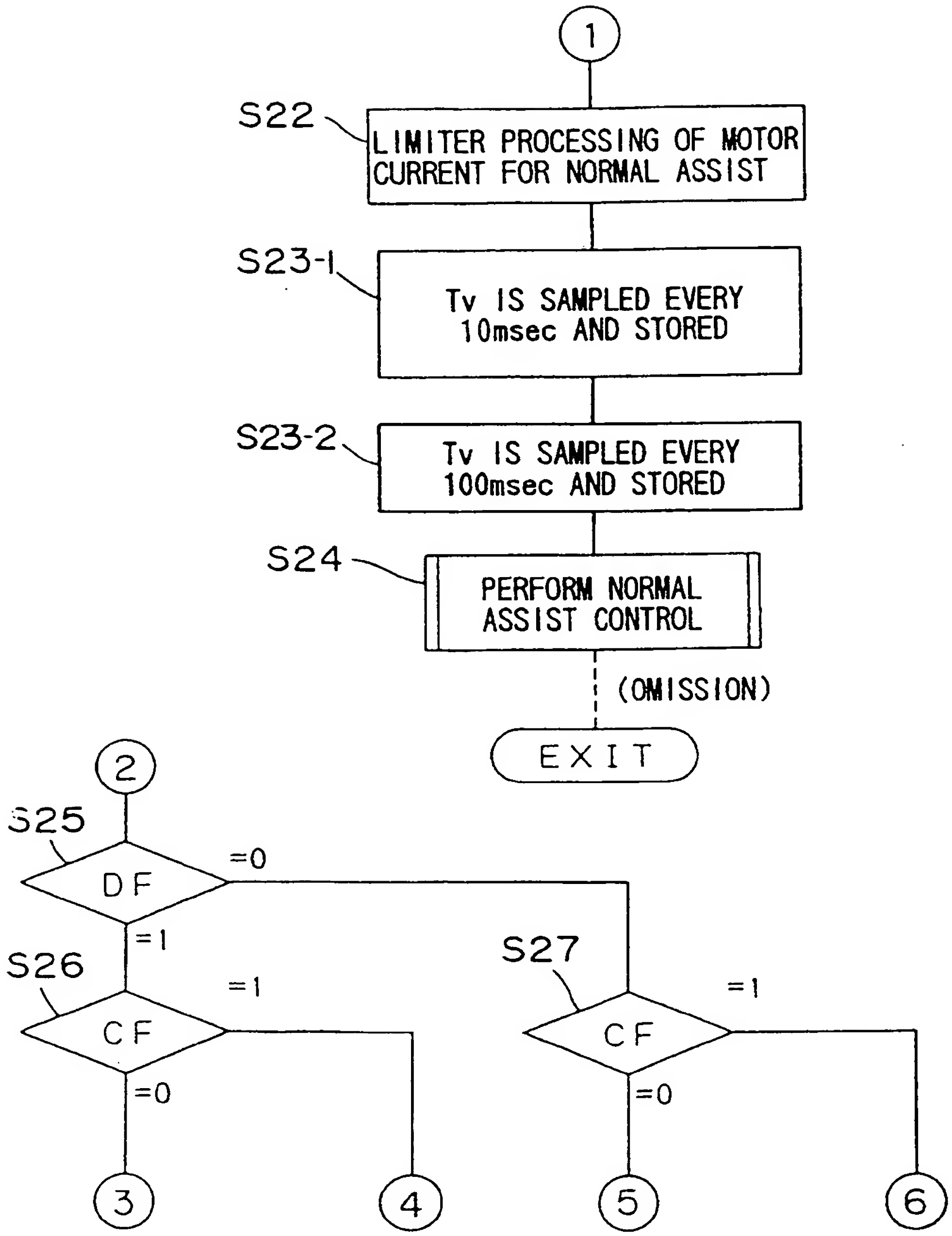
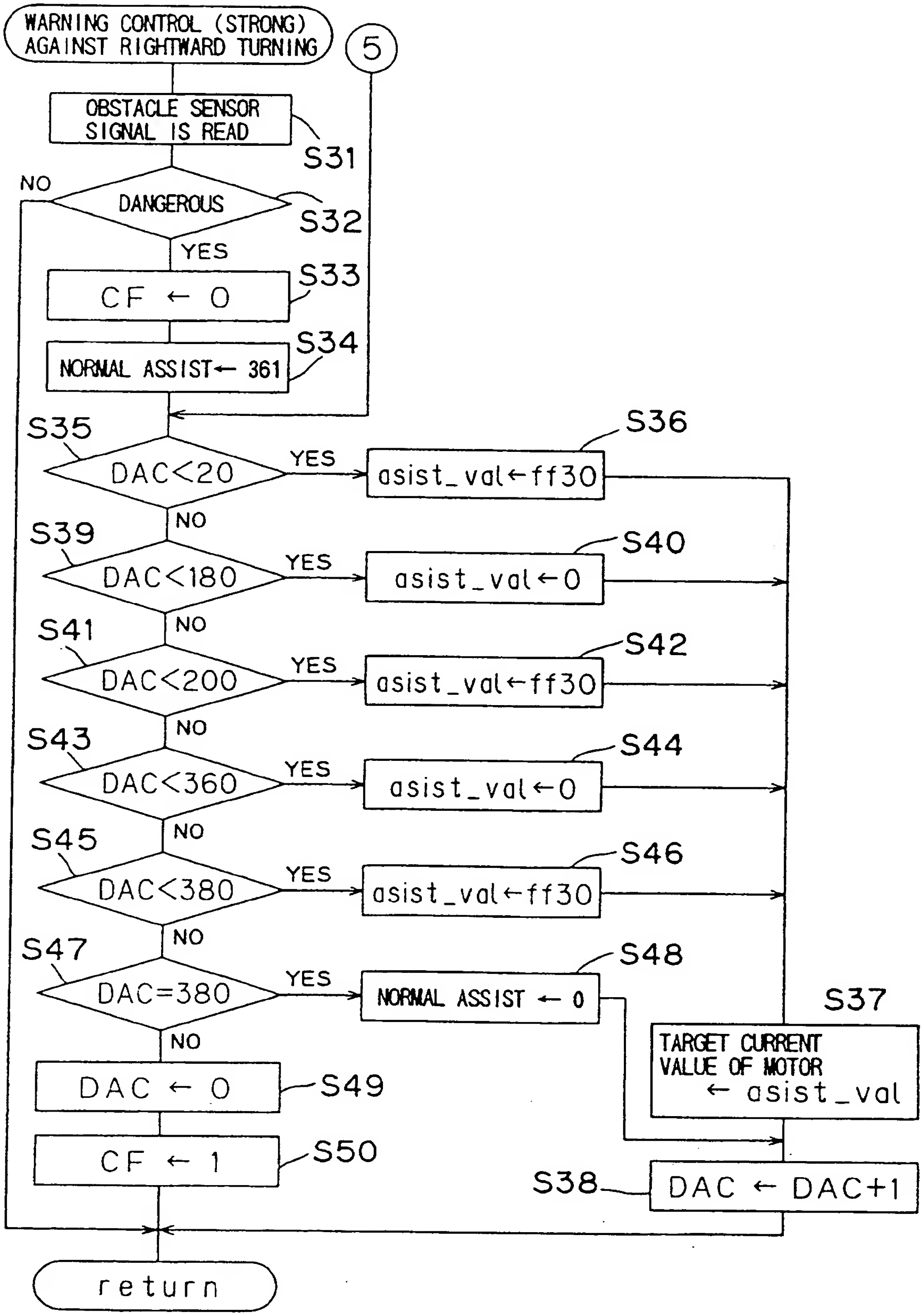

INTERRUPTION HANDLING
(OMISSION)
S1
LIMITER PROCESSING
S2
DAC
>0
=0
S3
DF
=0
=1
S4
Tv≧2.3V
NO
YES
S5
CF ← 0
S6
Tv≦2.7V
NO
YES
S7
CF ← 0
S8
Tv<2.5V
NO
YES
S9
Tv>1.9V
YES
NO
S11
Tv<3.1V
YES
NO
S10
DF ← 1
S12
DF ← 0
S13
CF
=1
=0
S14
DF
=0
=1
S21
DF
=0
=1
S15
Tv 50msec BEFORE > 1.9V
NO
YES
S18
Tv 50msec BEFORE < 3.1V
NO
YES
S17
WARNING FOR LEFTWARD(STRONG)
S20
WARNING FOR RIGHTWARD(STRONG)
S16
WARNING FOR LEFTWARD(MILD)
S19
WARNING FOR RIGHTWARD(MILD)
1
2

FIG. 7

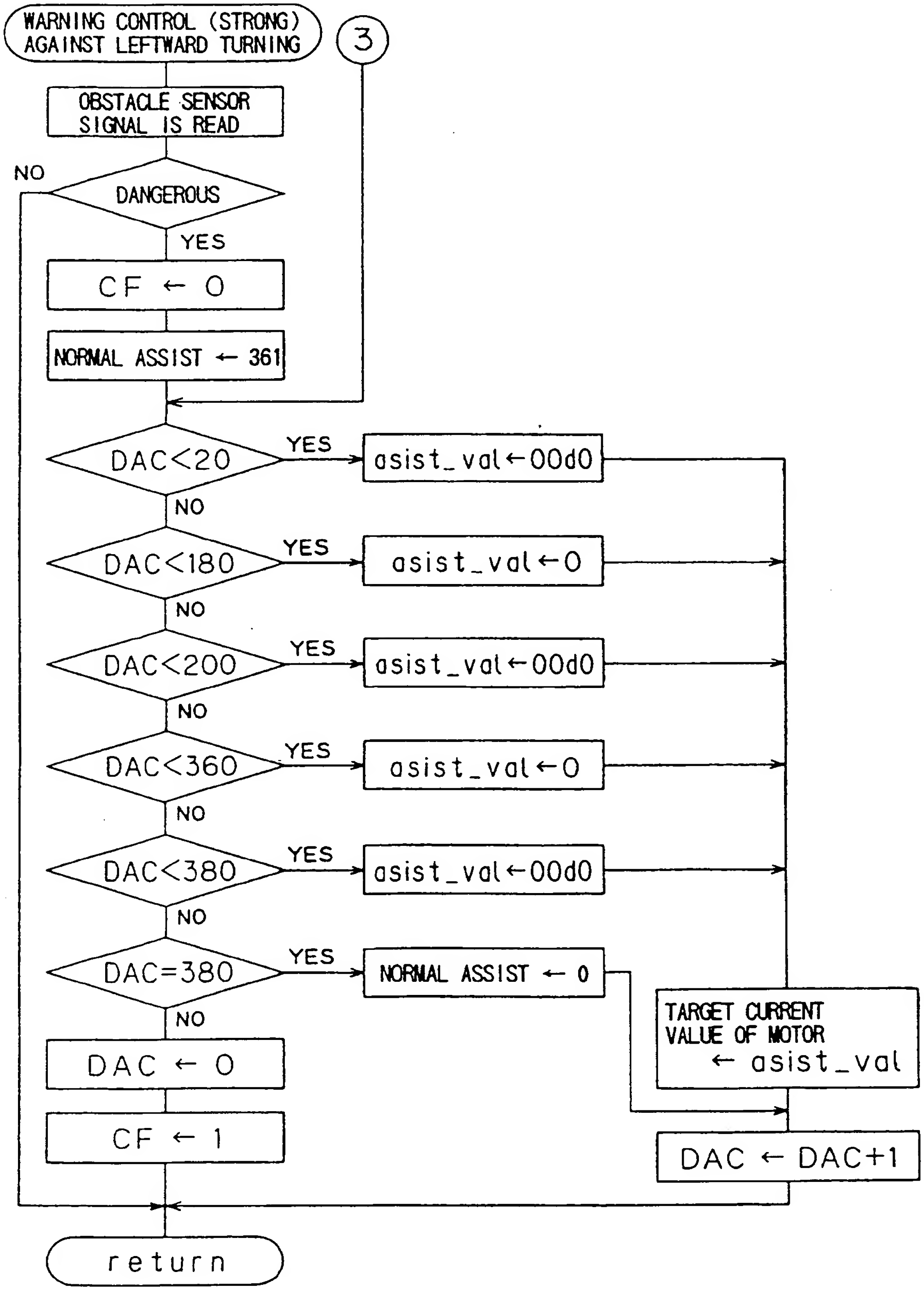

1
S22
LIMITER PROCESSING OF MOTOR CURRENT FOR NORMAL ASSIST
S23-1
Tv IS SAMPLED EVERY 10msec AND STORED
S23-2
Tv IS SAMPLED EVERY 100msec AND STORED
S24
PERFORM NORMAL ASSIST CONTROL
(OMISSION)
EXIT
2
S25
DF
=0
=1
S26
CF
=1
=0
S27
CF
=1
=0
3
4
5
6

F I G. 8

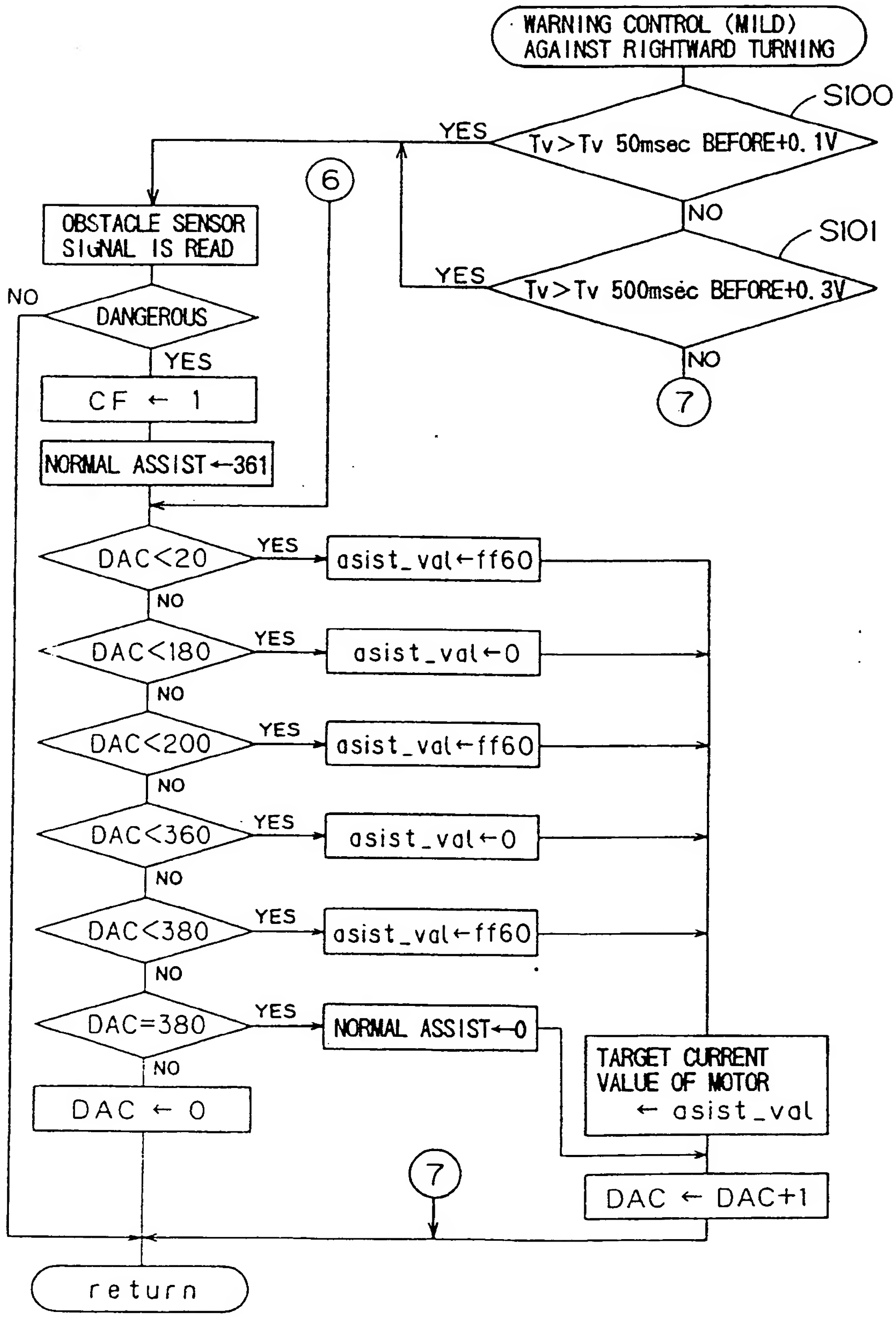


WARNING CONTROL (STRONG) AGAINST RIGHTWARD TURNING
5
OBSTACLE SENSOR SIGNAL IS READ
S31
DANGEROUS
S32
NO
YES
CF ← 0
S33
NORMAL ASSIST ← 361
S34
S35
DAC<20
YES
asist_val←ff30
S36
NO
S39
DAC<180
YES
asist_val←0
S40
NO
S41
DAC<200
YES
asist_val←ff30
S42
NO
S43
DAC<360
YES
asist_val←0
S44
NO
S45
DAC<380
YES
asist_val←ff30
S46
NO
S47
DAC=380
YES
NORMAL ASSIST ← 0
S48
NO
S37
TARGET CURRENT VALUE OF MOTOR ← asist_val
DAC ← 0
S49
CF ← 1
S50
S38
DAC ← DAC+1
return

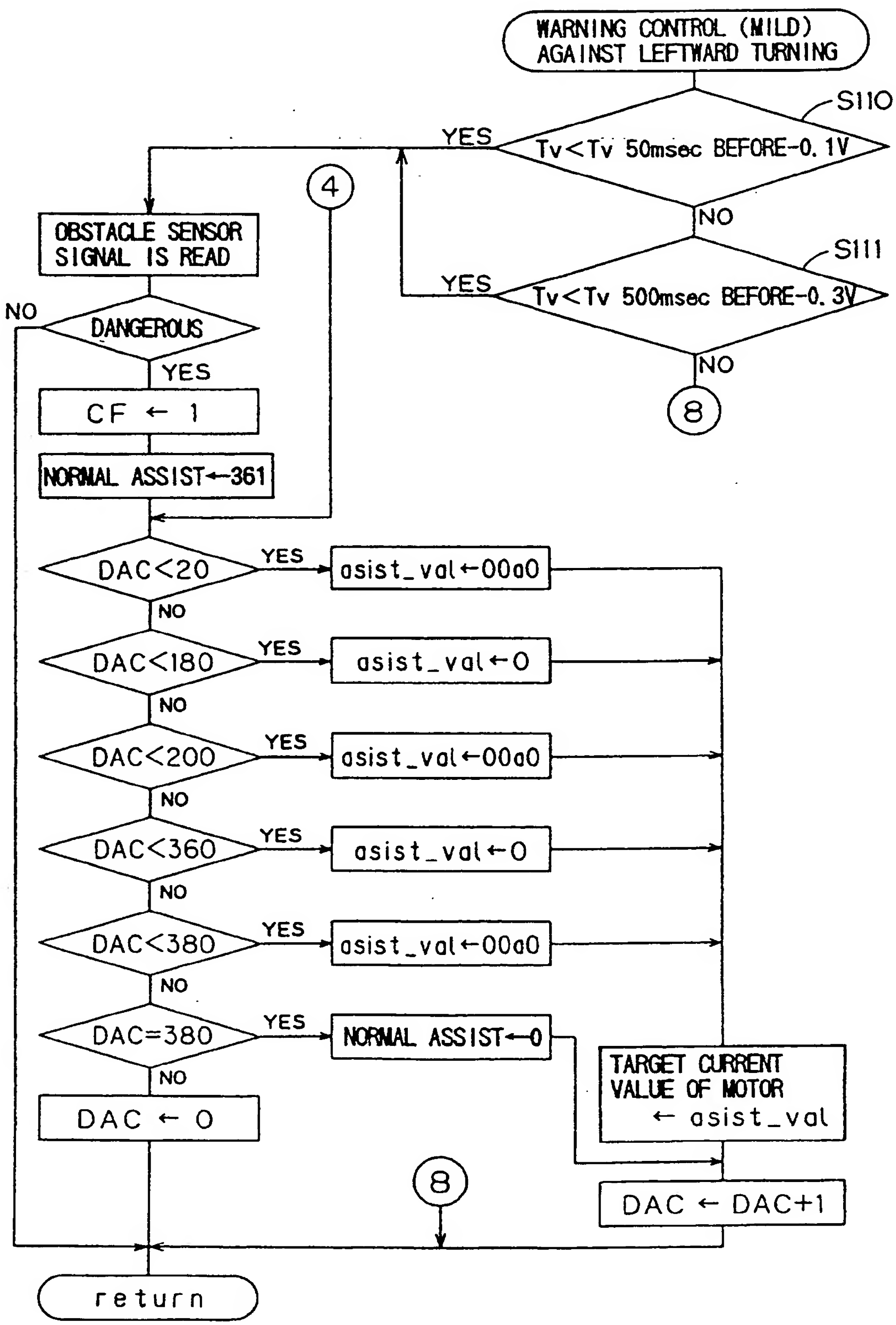
F I G. 9


WARNING CONTROL (STRONG) AGAINST LEFTWARD TURNING
3
OBSTACLE SENSOR SIGNAL IS READ
DANGEROUS
NO
YES
CF ← 0
NORMAL ASSIST ← 361
DAC<20
asist_val←00d0
DAC<180
asist_val←0
DAC<200
asist_val←00d0
DAC<360
asist_val←0
DAC<380
asist_val←00d0
DAC=380
NORMAL ASSIST ← 0
TARGET CURRENT VALUE OF MOTOR ← asist_val
DAC ← 0
CF ← 1
DAC ← DAC+1
return

F I G. 10


WARNING CONTROL (MILD) AGAINST RIGHTWARD TURNING
S100
Tv>Tv 50msec BEFORE+0. 1V
YES
NO
S101
Tv>Tv 500msec BEFORE+0. 3V
YES
NO
7
6
OBSTACLE SENSOR SIGNAL IS READ
DANGEROUS
NO
YES
CF ← 1
NORMAL ASSIST←361
DAC<20
asist_val←ff60
DAC<180
asist_val←0
DAC<200
asist_val←ff60
DAC<360
asist_val←0
DAC<380
asist_val←ff60
DAC=380
NORMAL ASSIST←0
TARGET CURRENT VALUE OF MOTOR ← asist_val
DAC ← 0
DAC ← DAC+1
7
return

F I G. 11


WARNING CONTROL (MILD) AGAINST LEFTWARD TURNING
S110
Tv<Tv 50msec BEFORE-0.1V
YES
NO
S111
Tv<Tv 500msec BEFORE-0.3V
YES
NO
8
4
OBSTACLE SENSOR SIGNAL IS READ
DANGEROUS
NO
YES
CF ← 1
NORMAL ASSIST←361
DAC<20
asist_val←00a0
DAC<180
asist_val←0
DAC<200
asist_val←00a0
DAC<360
asist_val←0
DAC<380
asist_val←00a0
DAC=380
NORMAL ASSIST←0
DAC ← 0
TARGET CURRENT VALUE OF MOTOR ← asist_val
DAC ← DAC+1
8
return

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 718 173 A3

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(71) Applicant: KOYO SEIKO CO., LTD.
Chuo-ku Osaka 542 (JP)

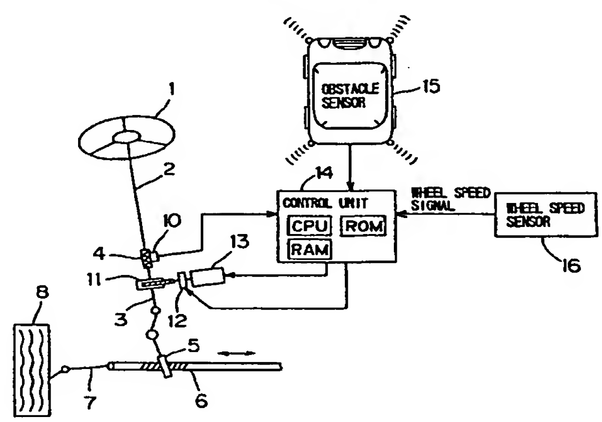
(72) Inventors:
- Shimizu, Yoshinobu, c/o Seiko Co., Ltd. Osaka 542 (JP)
- Nakano, Shiro, c/o Seiko Co., Ltd. Osaka 542 (JP)

(74) Representative:
Bohnenberger, Johannes, Dr. et al
Meissner, Bolte & Partner
Postfach 86 06 24
81633 München (DE)

(54) **Electric power steering system**

(57) An electric power steering system of this invention can inform the driver of potential danger before a vehicle enters a dangerous situation. The occurrence of dangerous situations is determined based on a signal from an obstacle sensor (15). If a steering wheel (1) is turned in a dangerous situation, a warning control is performed by control means (14) on a motor (13). The motor outputs a torque for t1 second, for example, which counters against turning of the steering wheel (1). Then, the motor enters a "non-assist" state wherein no current is applied thereto for t2 second. If an intermittent counter torque is applied by the motor, it is hard to turn the steering wheel. The steering wheel is caused to vibrate, thereby preventing the vehicle from being steered to collide with an obstacle. The driver is warned of the danger through the vibration caused in the steering wheel.

FIG. 2



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EUROPEAN SEARCH REPORT

Application Number
EP 95 11 9962

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	EP 0 556 870 A (KOYO SEIKO CO) 25 August 1993 * abstract *	1	B62D6/00 //B62D101:00, B62D109:00, B62D113:00, B62D137:00, B62D153:00
A	---	4	
P,Y	PATENT ABSTRACTS OF JAPAN vol. 095, no. 011, 26 December 1995 & JP 07 215144 A (MITSUBISHI MOTORS CORP), 15 August 1995, * abstract *	1	
A,P	---	2,3	
A	JP 05 113 822 A (MAZDA MOTOR CORP) 7 May 1993 -& US 5 485 892 A (FUJITA KENJI) 23 January 1996 * column 9, line 9 - line 29 * * column 10, line 51 - column 11, line 10 * * figure 20 * ---	1	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	EP 0 582 236 A (TAKATA CORP) 9 February 1994 * column 4, line 31 - column 6, line 3 * * column 14, line 1 - line 9 * * figure 1 * -----	1	B62D G01S

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 September 1997	Kulozik, E

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